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# The DHSmart model for smart product-service system (smart PSS): dynamic, data-driven, human-centred

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**Abstract**

Despite its transformative impact, a systematic approach to Smart PSS development remains elusive. Addressing this, the study introduces a dynamic conceptual model named DHSmart and its accompanying canvas, adaptable to various contexts and technological advancements. Notably, it offers a structured approach to designing ‘Smart’ in Smart PSS, capturing the interplay between data, humans, and smart systems while directing digitalisation that achieves competitive advantage. It also serves as a unifying framework, enabling meaningful interdisciplinary contributions in theory and practice.

*Keywords: smart product-service systems, digitalisation, servitisation, data-driven design, human-centred design*

## 1. Introduction

Product-Service System (PSS) was initially conceptualised as a system integrating products and services to deliver utility (Goedkoop et al., 1999; Mont, 2002). The increasing role of technology marked a transition from conventional PSS to Smart PSS (Valencia et al., 2014). Despite the significance of Smart PSS being recognised, this concept is still in its nascent stages, and a systematic methodology for its development remains absent (Cong et al., 2020, 2022; Liu, Ming and Song, 2019; Wang, Chen, Li, et al., 2021; Zhang et al., 2023). The integration of digitalisation (Zheng et al., 2019) and servitisation (Goedkoop et al., 1999; Mont, 2002) forms the bedrock of Smart PSS, emphasising the necessity for both the capabilities afforded by digitalisation and the human-centred focus advocated by Service-Dominant (S-D) logic. In this context, ***'Smart'*** reflects the characteristics and capabilities afforded by digitalisation. However, despite extensive research on digitalisation capability, there remains a notable lack of structured guidance on designing 'Smart' in Smart PSS to ensure real value creation (Porter and Heppelmann, 2014). Moreover, in an era where Smart artefacts are increasingly responsive to user inputs and conditions (Liu, Ming and Song, 2019; Rinaldi et al., 2016; Wilson and Daugherty, 2018), the human role transcends mere recipients of value. The intricate interplay between Smart artefacts and the user elevates their role to an integral component of the Smart PSS, an area that has also received insufficient attention. This argument is particularly relevant due to ethical considerations, which are increasingly important in the design and implementation of technologies that closely interact with humans (CDDO, 2020; Gorkovenko et al., 2020; Lindley et al., 2020; Streitz et al., 2019). In this study, the term 'human' is used interchangeably with 'user' to maintain consistency with established concepts in the literature, such as Human-Centred Design (HCD), although also extends to other stakeholders. These interrelated gaps in systematic methodology for Smart PSS design, defining 'Smart' in Smart PSS, and the comprehensive inclusion of the interplay between Smart artefacts and the user present not only academic concerns but carry practical implications referred to as the 'digitalisation paradox'. This paradox, where digitalisation investments fail to yield expected revenue growth (Gebauer et al., 2020), further highlights the need for a systematic approach to Smart PSS design and development.

This study aims to develop a systematic approach to Smart PSS that not only elucidates the Smart attribute but also intricately integrates the human dimension, acknowledging their critical impact in shaping Smart PSS and its performance. To achieve this aim, the objective is to develop a conceptual model for Smart PSS, characterised by a dynamic nature that is resilient to technological advancements and adaptable to diverse contexts, thereby ensuring its long-term applicability and relevance in both academic and practical settings. Informed by the identified gaps and guided by the defined objective, the following research questions (RQs) are formulated: RQ1. What are Smart PSS's key components and aspects? RQ2. How can Smart PSS's evolving nature and complexity be effectively captured? and RQ3. How can Smart PSS design be guided to deliver real value while maintaining a competitive edge?

## 2. Methodology

This study employed the Grounded Theory (GT) method to develop a conceptual model for Smart PSS. GT, as a qualitative method for creating conceptual frameworks (Charmaz, 2006) and investigating evolving concepts and complex phenomena, such as Smart PSS, where new insights are needed (Chun Tie et al., 2019; Glaser and Strauss, 1967), is particularly apt for this study. GT underpins the literature selection and data analysis processes in this study, enabling a systematic analysis and synthesis of the existing literature on Smart PSS, as elaborated in the following subsections.

### 2.1. Selection of literature

A comprehensive search query was developed to study Smart PSS from a human-centred perspective, focusing on three primary dimensions: *Smart*, *PSS*, and *Human*. The incorporated keywords for *Smart* were: (smart OR intelligent OR 'artificial intelligence' OR AI OR 'machine learning' OR digital*), for *PSS* were: ('product-service' OR PSS OR servitisation), and for *Human* were: (human* OR people OR person OR user OR customer* OR consumer* OR individual* OR stakeholder* OR patient*). These aspects were linked using the Boolean operator 'AND', and the search was restricted to the 'Title' and 'Author Keywords' fields. The literature search spanned from 2014 to 2023, aligning with the emergence of Smart PSS (Valencia et al., 2014). Only articles and conference papers in English were included. Scopus and Web of Science were chosen as research databases for their extensive interdisciplinary coverage (Carrera-Rivera et al., 2022). The initial search yielded 66 records from Scopus and 53 from Web of Science as of the last update on 17 August 2023. The limited number of records suggests that the field is still emerging, with a particular gap in the literature concerning the human dimension in Smart PSS. During the review process, articles that were duplicates, irrelevant to the field (e.g., those on Rheumatology), or not focused on the user dimension (such as those dealing with B2B business models) were excluded. This exclusion was based on examining titles and abstracts and a more detailed review where necessary. Throughout coding and identifying emerging patterns, an additional 25 articles were selected in line with GT principles (Chun Tie et al., 2019; Glaser and Strauss, 1967), primarily sourced from the references of the initially reviewed papers. Consequently, a total of 51 articles were thoroughly coded and analysed, forming the foundational literature for this study.

### 2.2. Data analysis

Data analysis in this study adhered to GT principles, beginning with coding the initial literature set using NVivo software. This initial coding led to the inclusion of the second set of literature as a theoretical sample, enriching the analysis by adding depth to the identified key components and overlooked aspects of Smart PSS from the initial phase. This iterative process aligns with GT principles (Chun Tie et al., 2019; Glaser and Strauss, 1967). The final coding framework is detailed in Figure 1. Concurrently, an interpretive review of the same set of literature was undertaken to ensure theoretical sensitivity, which is crucial for identifying and understanding significant data elements and patterns, thereby contributing to developing a robust conceptual model (Chun Tie et al., 2019). The integration of insights from both the structured coding and the interpretive review culminated in the development of a dynamic conceptual model for Smart PSS.

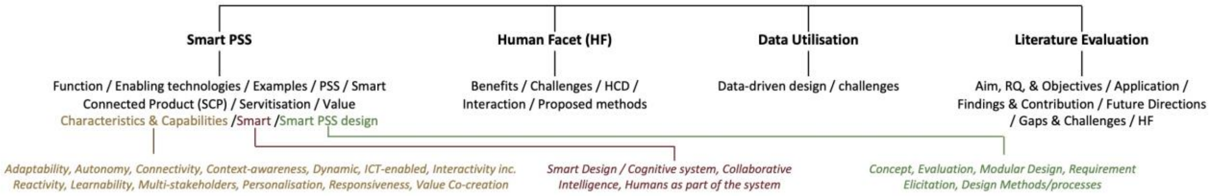


**Figure 1. Theoretical coding in data analysis**

## 3. Tracing the theoretical trajectory of Smart PSS

The Product-Service System (PSS) concept originated from a paradigm shift from the industrial economy with a primary focus on commodification to the Functional Service Economy, in which the object of the sale is utility and performance (Goedkoop et al., 1999; Mont, 2002; Stahel, 2010). Initially, PSS was conceptualised as a system integrating products and services, supported by networks and infrastructure, to deliver utility (Goedkoop et al., 1999). Tukker (2004) categorised PSS to delineate the varying modes through which utility is delivered, where the focus progressively shifts from the product to the result provided. This aligns with the Service Economy's business model, which prioritises functional performance and centralises utilisation value as the core economic metric (Stahel, 2010).

As PSS evolved, the increasing role of technology marked a transition to Smart PSS (Chang et al., 2023; Chen et al., 2020; Wang, Chen, Li et al., 2021; Zhou et al., 2023). This evolution can be contextualised within the broader framework of IT-driven transformations, as Porter and Heppelmann (2014) outlined. The emergence of PSS coincided with the second wave of IT-driven transformation, marked by unprecedented connectivity (Zheng et al., 2019). Information Technology (IT) became an integral component of the product in the third wave, leading to the emergence of Smart Connected Products (SCPs) (Porter and Heppelmann, 2014). This technological evolution has, in turn, given rise to the Smart PSS concept, further enriching the functionality and performance of these systems (Carrera-Rivera et al., 2022; Chang et al., 2023; Liu, Ming and Song, 2019; Negash et al., 2023; Zheng et al., 2019).

As digital technology became an integral component of the product, the embedded sensors, connectivity, and data analytics capabilities have enabled Smart PSS to collect data about the dynamic aspects of its environment, such as location and temperature, and accordingly perform real-time data-driven functions. This ability to dynamically respond and adapt to changing environmental conditions and user requirements to deliver personalised and timely services is known as context awareness (Bu et al., 2020; Carrera-Rivera et al., 2022; Cong et al., 2020; Valencia et al., 2014; Wang, Chen, Li, et al., 2021; Wang, Chen, Zheng, et al., 2021). As such, the context at the micro level–limited to each specific Smart PSS–is pivotal for the detailed design due to its potential to elevate the smartness level and utility. However, it should not overshadow the significance of the market dynamics, encompassing all external elements that influence a company's strategic decisions and value offerings. Therefore, context at the macro level, such as market conditions, type of user, and the discovered patterns from accumulated sensor data over time, is also pivotal in informing the value proposition of the Smart PSS, thereby determining its overall design (Porter and Heppelmann, 2014; Valencia et al., 2014) or deriving innovation.

In this section, the fundamentals of the Smart PSS have been explored, tracing its evolution to delineate its core components and their interrelationships. The symbiotic relationship between products, services, and digitalisation capabilities, facilitated by supporting networks and infrastructure, has been a consistent theme in the reviewed literature. Furthermore, the context dependency of Smart PSS is underscored by its influence at the micro level, being instrumental in detailed design, and at the macro level, shaping the overall design strategy and design innovation. Yet, the concept of 'utility' remains the linchpin, encapsulating the value delivered by Smart PSS, which should resonate with and reflect the business's value proposition. The following sections will explore overlooked aspects of Smart PSS and propose a novel conceptual model to enrich both the theoretical and practical landscapes of Smart PSS.

## 4. The overlooked aspects of Smart PSS

This section explores two critical yet often overlooked aspects of Smart PSS: the Smart attribute and the intricate interplay between humans and Smart PSS. The following subsections illuminate the nuanced nature and implications of these aspects, indispensable in designing Smart PSS that not only deliver real value but also maintain a competitive edge.

## 4.1. The Smart component: the constitution of 'Smart' in Smart PSS

The Smart attribute is often ambiguously employed as a catch-all term, merely denoting advanced technology and connectivity (Horváth, 2021; Negash et al., 2023; Porter and Heppelmann, 2014; Valencia et al., 2014). The absence of a structured and unified framework to define Smart in Smart PSS can be attributed to its fluid and multifaceted nature, which originates from three key factors. Firstly, continual technological advancement acts as a catalyst, introducing emerging characteristics and capabilities that question previous works' comprehension. For instance, Rijsdijk and Hultink (2009) defined 'smartness' in products by identifying seven characteristics: autonomy, adaptability, reactivity, multifunctionality, cooperation, human-like interaction, and personality. However, this framework predates technological advancements such as context-awareness, which now challenge the earlier conceptions of Smart. Second, the context-dependent nature of Smart PSS questions the relevance of existing studies, as it results in a diversity of Smart characteristics and capabilities across various contexts of use (Porter and Heppelmann, 2014; Valencia et al., 2014). For example, Smart in an energy management system may refer to adaptability (Honeywell, 2023), whereas in healthcare applications, it could imply detective analytics (Omron, 2023). In an effort to establish a comprehensive approach, Horváth (2021) identified characteristics of Smart value carriers, including personalisation, connectedness, situatedness, awareness, adaptiveness, and proactivity. Although Horváth (2021) suggests they are broadly applicable, this list overlooks essential attributes such as learnability and autonomy, which are critical in specific contexts like autonomous vehicles. Such an absence raises concerns about the work's relevance across diverse contexts. Third, the Smart attribute has different levels of sophistication. These levels are usually attributed to the digitalisation capability (Horváth, 2021; Zheng et al., 2019). Zheng et al. (2019) offer a taxonomy with five smartness levels–smart connectivity, smart analytics, digital twin, cognition, and autonomy–which aids in understanding the nuances of Smart attribute. However, the applicability of this taxonomy, whether viewed hierarchically or non-hierarchically, is debatable. For instance, not all autonomous systems incorporate a 'digital twin,' challenging its hierarchical placement. From a non-hierarchical perspective, the taxonomy faces challenges in inclusivity. It can be exemplified by the Rain Bird irrigation system that operates autonomously while lacking cognitive capability (Rain Bird, 2023). This indicates that autonomy alone does not necessarily represent the highest level of smartness. Therefore, it is concluded that the Smart attribute has a complex construct, transcending mere static characteristics and digitalisation capabilities. This attribute exists on a spectrum and is experienced by the extent of capabilities afforded by digitalisation–an overlooked aspect that contributes significant complexity and subtlety to Smart PSS design. A representative example can be a *context-aware* heating system, where the capability of *adaptability* ranges from simple responses to ambient temperature changes to more complex adjustments based on user preferences and occupancy patterns (Honeywell, 2023).

The diversity of scholarly perspectives on Smart within Smart PSS literature further underscores the intricacy involved in its construct. Notably, Zheng et al. (2019) posit that the scope of Smart PSS could include IoT-enabled PSS, a precursor phase to Smart PSS. This indicates a great emphasis on digitalisation capabilities, overlooking the complex nature of the 'Smart' attribute that emerges as a *result* of these digital capabilities. Figure 2 outlines the most frequently cited features related to the Smart attribute, irrespective of whether they are referred to as 'characteristic' or 'capability', and also when the underlying meaning of the Smart feature aligns, allowing for categorisation under the same heading.

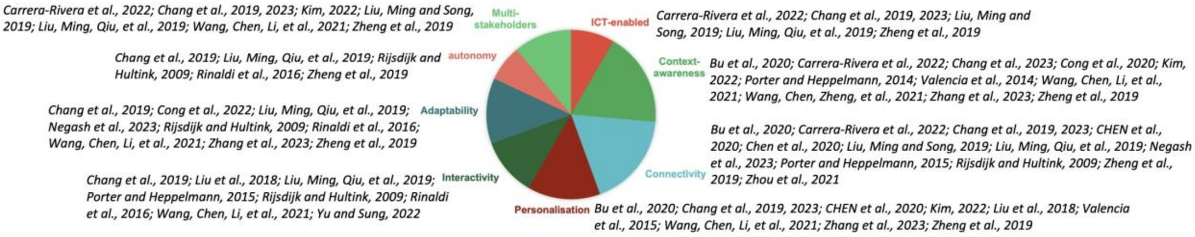


**Figure 2. Frequently cited Smart features in literature**

The foregoing discussion highlights the complexity of the Smart attribute and the significant oversight of its indispensable role in Smart PSS design and development. Porter and Heppelmann (2015) have previously proposed Smart as a core component of SCPs, mainly denoting digitalisation capability. This study suggests the inclusion of the Smart attribute as an integral component of Smart PSS, embedding the characteristics and capabilities afforded by digitalisation capability and the extent to which they can be experienced in a specific Smart PSS. As such, it is distinct from digitalisation capabilities like IoT and AI, which serve as enablers to afford those Smart features. This is to acknowledge that the Smart attribute is relative to the subtle interplay between the entire system components that can be experienced at different levels of sophistication, guiding a nuanced definition that aligns with the strategic objectives and design considerations of a specific Smart PSS. The subsequent section will explore the human dimension as the user of the Smart PSS that intertwines with the Smart attribute to drive value.

## 4.2. The human component: beyond a passive human inclusion

Anchored in Service-Dominant (S-D) logic and servitisation principles to meet personalised demands (Carrera-Rivera et al., 2022; Chang et al., 2019; Liu, Ming, Qiu, et al., 2019; Mont, 2002), the centrality of the user in Smart PSS is indisputable. The existing discourse on the user dimension in Smart PSS mainly adheres to Human-Centred Design (HCD) principles defined by the ISO (2019), with added emphasis on data-driven design and real-time system responsiveness and adaptability. They predominantly focus on value co-creation (Carrera-Rivera et al., 2022; Chang et al., 2019; Costa et al., 2018; Liu et al., 2018; Liu, Ming and Song, 2019; Liu, Ming, Qiu, et al., 2019; Zheng et al., 2019), requirements elicitation (Chang et al., 2023; Chen et al., 2020; Cong et al., 2022; Wang, Chen, Li, et al., 2021), User Experience (UX) (Chen et al., 2020; Yu and Sung, 2022; Zheng et al., 2019; Zhou et al., 2022), and user context (Bu et al., 2020; Carrera-Rivera et al., 2022; Cong et al., 2020; Wang, Chen, Li, et al., 2021; Wang, Chen, Zheng, et al., 2021). The '*passive human inclusion*' is termed to describe the approach observed in these studies, where humans are represented by data rather than their direct involvement and input in the operational loop, as seen in the Human-in-the-Loop (HITL) design model. Although invaluable, many of the current human-centred, data-driven approaches are confined to the traditional HCD emphasis on Usability, Accessibility, UX, and Satisfaction (Giacomin, 2014; ISO, 2019; Norman, 2013). However, interactions with smart systems are multifaceted, surpassing these aspects. Smart PSS's value is mainly co-created through Human-System Interaction (HSI) (Carrera-Rivera et al., 2022; Chang et al., 2019; Costa et al., 2018; Liu et al., 2018; Liu, Ming and Song, 2019; Liu, Ming, Qiu, et al., 2019; Zheng et al., 2019). However, humans transcend the role of mere users in this context by being integral to the system's operation and directly influencing its performance. For instance, a user actively informs the system's Smart functionality by programming or adjusting the thermostat in a smart heating system (Honeywell, 2023). Such personalisation extends beyond mere usability within HSI, as the user's input directly shapes the system's operation and efficiency.

As Smart PSS ascend the smartness spectrum, they shift from relying on direct human input to being predominantly data-driven (Porter and Heppelmann, 2014). Nonetheless, the user's impact on design remains indisputable, even in highly autonomous systems. Using user data for design and smart functionality introduces ethical challenges, such as blackboxing that conceals the rationale behind Smart functions from users (Gorkovenko et al., 2020; Streitz et al., 2019). Ethical design must, therefore, address human-related aspects, such as data collection parameters, informed consent, user control, and transparency (CDDO, 2020). These considerations extend beyond the usability focus of traditional HCD, positioning the human as an integral system component in defining the boundary of its Smart functionality. Despite the recognised significance of ethical implications (CDDO, 2020; Gorkovenko et al., 2020; Streitz et al., 2019), there remains a gap in design methodologies that fully incorporate user influence as a mediator of Smart characteristics and capabilities.

Driven by presented gaps, the *'active human inclusion'* is termed to incorporate the influence of human interaction on the performance of Smart artefacts, which can also systematically foster ethical and human-centred design. Wilson and Daugherty (2018) highlight this by proposing that smart systems reach optimal performance when harmoniously integrating human cognition and artificial intelligence (AI). They defined two distinct human-machine collaboration modes, 'humans assisting machines' and 'machines assisting humans,' analogous to the Human-in-the-Loop (HITL) and Human-on-the-Loop

(HOTL) models in system design. In HITL, users are actively involved in the operation loop, such as decision-making, to assist the system in achieving its final goal (Holzinger, 2016; Nguyen Ngoc et al., 2022; Wilson and Daugherty, 2018). Conversely, in HOTL, users act as overseers, providing only strategic input instead of constant real-time participation in operations (Nguyen Ngoc et al., 2022; Wilson and Daugherty, 2018). Thus, HOTL can enhance AI and machine learning (ML) performance while facilitating a balance between system autonomy and user control as an ethical design requirement (Lindley et al., 2020). These concepts surpass the HCD's traditional scope, providing avenues to harness the interplay between the user and Smart artefact (Wilson and Daugherty, 2018). Despite their potential to refine Smart PSS design, the application of these concepts in this field remains an underexplored area. In light of the complex interplay between the human and Smart PSS, this study concludes recognising the human as an integral component of Smart PSS is not merely a theoretical proposition but a practical imperative to guide the Smart PSS design in delivering real value to both humans and businesses alike. This integration, from the outset, enriches the theoretical underpinnings of Smart PSS and promotes a design approach that equally prioritises both human and technological considerations.

## 5. A dynamic conceptual model for Smart PSS

The provided insights in the preceding sections, in line with the study's Research Questions (RQ), laid the foundation for developing a dynamic conceptual model for Smart PSS, as depicted in Figure 3. The model, named ***DHSmart***, employs visual cues to illustrate the complex interplay among key Smart PSS components, depicting a bottom-up shift in their roles and influences across the smartness spectrum, enriching its dynamic nature. The *DHSmart Model Canvas*, illustrated in Figure 4, is presented as an accompanying practical tool. It incorporates a snapshot of the Samsung SmartThings app as a real-world example, blending its actual specifications with informed extrapolations. Notably, the depiction of the smartness spectrum, distinguished by colour-coded texts, is an interpretative illustration, as this nuanced concept is rarely explored in both practical applications and academic discourse on Smart PSS. The provided example showcases the interplay between the model's components, the bottom-up shift in their relative significance, and the structured guidance it can offer on Smart PSS design, thereby demonstrating the model's practical application and adaptability in the real world. This section provides a comprehensive elaboration of the proposed DHSmart model.

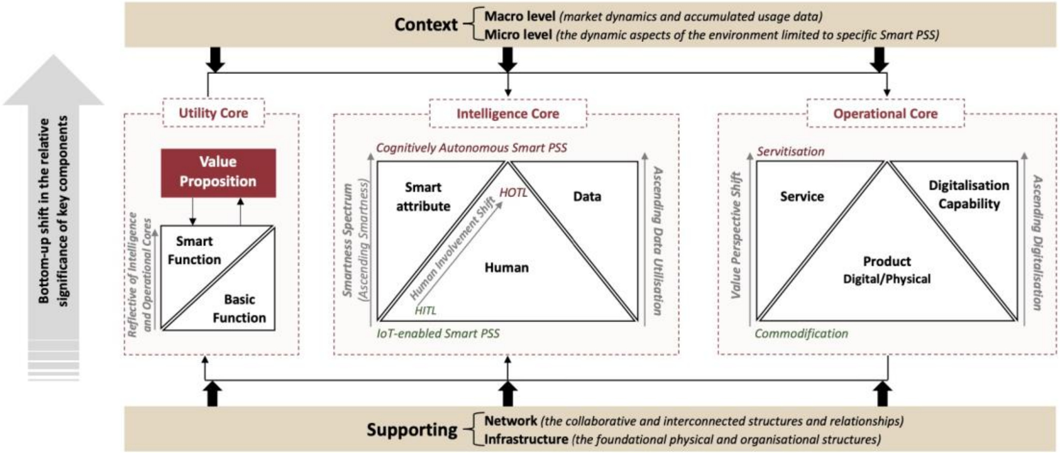
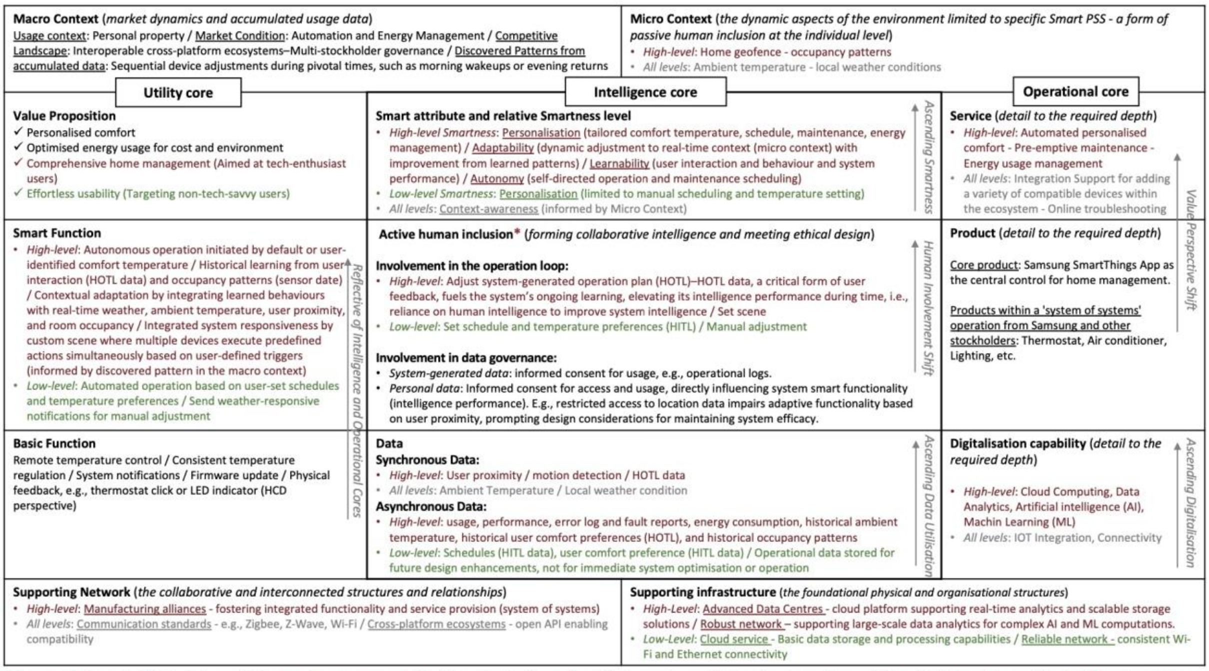


**Figure 3. The DHSmart model for Smart PSS: dynamic, data-driven, and human-centred**

In response to RQ1, the ***'operational core'*** encapsulates key components, including the *product*, *service*, and *digitalisation capabilities*, that form the foundation of PSS. This core is supported by a foundational ***network and infrastructure*** as the basis for delivering and maintaining integrated PSS offerings (Goedkoop et al., 1999). Within this core, technical and technological feasibilities are scrutinised, and system requirements are mapped to deliver value. Inspired by Tukker's (2004) categorisation of PSS types, this core demonstrates a bottom-up shift from a product-based value (commodification) to a service-oriented perspective that emphasises delivering value through utility and outcomes.



**Macro Context** (*market dynamics and accumulated usage data*)
Usage context: Personal property / Market Condition: Automation and Energy Management / Competitive Landscape: Interoperable cross-platform ecosystems–Multi-stockholder governance / Discovered Patterns from accumulated data: Sequential device adjustments during pivotal times, such as morning wakeups or evening returns

**Micro Context** (*the dynamic aspects of the environment limited to specific Smart PSS - a form of passive human inclusion at the individual level*)
- *High-level*: Home geofence - occupancy patterns
- *All levels*: Ambient temperature - local weather conditions

**Utility core**

**Value Proposition**
- ✓ Personalised comfort
- ✓ Optimised energy usage for cost and environment
- ✓ Comprehensive home management (Aimed at tech-enthusiast users)
- ✓ Effortless usability (Targeting non-tech-savvy users)

**Smart Function**
- *High-level*: Autonomous operation initiated by default or user-identified comfort temperature / Historical learning from user interaction (HOTL data) and occupancy patterns (sensor date) / Contextual adaptation by integrating learned behaviours with real-time weather, ambient temperature, user proximity, and room occupancy / Integrated system responsiveness by custom scene where multiple devices execute predefined actions simultaneously based on user-defined triggers (informed by discovered pattern in the macro context)
- *Low-level*: Automated operation based on user-set schedules and temperature preferences / Send weather-responsive notifications for manual adjustment

**Basic Function**
Remote temperature control / Consistent temperature regulation / System notifications / Firmware update / Physical feedback, e.g., thermostat click or LED indicator (HCD perspective)

**Intelligence core**

**Smart attribute and relative Smartness level**
- *High-level Smartness*: Personalisation (tailored comfort temperature, schedule, maintenance, energy management) / Adaptability (dynamic adjustment to real-time context (micro context) with improvement from learned patterns) / Learnability (user interaction and behaviour and system performance) / Autonomy (self-directed operation and maintenance scheduling)
- *Low-level Smartness*: Personalisation (limited to manual scheduling and temperature setting)
- *All levels*: Context-awareness (informed by Micro Context)

**Active human inclusion*** (*forming collaborative intelligence and meeting ethical design*)

**Involvement in the operation loop:**
- *High-level*: Adjust system-generated operation plan (HOTL)–HOTL data, a critical form of user feedback, fuels the system's ongoing learning, elevating its intelligence performance during time, i.e., reliance on human intelligence to improve system intelligence / Set scene
- *Low-level*: Set schedule and temperature preferences (HITL) / Manual adjustment

**Involvement in data governance:**
- *System-generated data*: informed consent for usage, e.g., operational logs.
- *Personal data*: Informed consent for access and usage, directly influencing system smart functionality (intelligence performance). E.g., restricted access to location data impairs adaptive functionality based on user proximity, prompting design considerations for maintaining system efficacy.

**Data**
**Synchronous Data:**
- *High-level*: User proximity / motion detection / HOTL data
- *All levels*: Ambient Temperature / Local weather condition

**Asynchronous Data:**
- *High-level*: usage, performance, error log and fault reports, energy consumption, historical ambient temperature, historical user comfort preferences (HOTL), and historical occupancy patterns
- *Low-level*: Schedules (HITL data), user comfort preference (HITL data) / Operational data stored for future design enhancements, not for immediate system optimisation or operation

**Operational core**

**Service** (*detail to the required depth*)
- *High-level*: Automated personalised comfort - Pre-emptive maintenance - Energy usage management
- *All levels*: Integration Support for adding a variety of compatible devices within the ecosystem - Online troubleshooting

**Product** (*detail to the required depth*)

Core product: Samsung SmartThings App as the central control for home management.

Products within a 'system of systems' operation from Samsung and other stockholders: Thermostat, Air conditioner, Lighting, etc.

**Digitalisation capability** (*detail to the required depth*)
- *High-level*: Cloud Computing, Data Analytics, Artificial intelligence (AI), Machin Learning (ML)
- *All levels*: IOT Integration, Connectivity

**Supporting Network** (*the collaborative and interconnected structures and relationships*)
- *High-level*: Manufacturing alliances - fostering integrated functionality and service provision (system of systems)
- *All levels*: Communication standards - e.g., Zigbee, Z-Wave, Wi-Fi / Cross-platform ecosystems - open API enabling compatibility

**Supporting infrastructure** (*the foundational physical and organisational structures*)
- *High-Level*: Advanced Data Centres - cloud platform supporting real-time analytics and scalable storage solutions / Robust network – supporting large-scale data analytics for complex AI and ML computations.
- *Low-Level*: Cloud service - Basic data storage and processing capabilities / Reliable network - consistent Wi-Fi and Ethernet connectivity

*** Compare the impact of this inclusion on design, e.g., in extreme cases of healthcare applications, where direct user intervention in system operations and data collection must be restricted while system errors can be fatal. In such cases, diminished user oversight demands increased data collection and sophisticated feedback mechanisms to maintain or improve system self-organisation and intelligence.**

**Figure 4. The DHSmart model canvas: practical accompanying tool and application showcase**

To address RQ2 and overlooked aspects, the ***'intelligence core'*** is introduced separately from digitalisation capabilities to ensure the model's adaptability to the evolving nature of Smart PSS and its relevance amidst technological advancements to guide the design of Smart in Smart PSS. This core dissects the complexity of the Smart construct shaped by the synergistic interplay between key components of the *Smart attribute*–encapsulating characteristics and capabilities afforded by digitalisation capability and the extent to which they can be experienced–*human*, and *data*. Pivotal for the design, the amalgamation of the Smart attribute and data as its main enabler transforms business functions, elevating data management to a critical business operation (Porter and Heppelmann, 2015). The model addresses the significance of data (Machchhar et al., 2022) by its integration as a key component of Smart PSS, spotlighting data-related requirements and ethical imperatives during the design and system lifecycle. As outlined, the human component is also intricately intertwined with the Smart attribute and data. Therefore, the 'active human inclusion' in the operational loop can significantly enrich the design of the Smart system (Nguyen Ngoc et al., 2022; Wilson and Daugherty, 2018) and weave ethical and HCD principles throughout the design journey. Interweaving human and data components facilitates comprehensive human inclusion, where direct user involvement gradually gives way to data about them. This study posits HITL and HOTL as the endpoints of this transition, delineating a continuum of human interaction with Smart PSS that is fundamental for intuitive design. Notably, the model underscores that the concern about the human role remains indispensable even in fully data-dependent scenarios, reinforcing ethical design. This transition also seamlessly aligns with the smartness spectrum, spanning basic IoT-enabled automation to advanced data-driven autonomy. Recognising this spectrum, where the smart attribute can be experienced in different levels of sophistication, is essential for understanding the construct of Smart, and it invites further scholarly exploration. This intelligence core thus provides a systematic approach to designing Smart in Smart PSS with clarity and creativity.

Addressing RQ3, the ***'utility core'*** is integrated to guide the delivery of real value to both the user and the business, adding a layer of sophistication and dynamism. Although the intelligence core underscores the significance of the Smart attribute in Smart PSS design, its role as a differentiator diminishes as smart features become ubiquitous (Liu et al., 2018). Similarly, while the operational core can mainly address Operational Effectiveness (OE)–the foundation for competitive advantage—it does not alone secure a lasting competitive edge (Porter and Heppelmann, 2014). The integration of the competitive advantage perspective is to ensure the model equips Smart PSS theory and practice to achieve both superior performance and competitive advantage. The utility core is thus introduced, incorporating the field's focus on functional performance and outcomes (Goedkoop et al., 1999; Mont, 2002; Tukker, 2004). This core embodies the *value* delivered by Smart PSS, along with the necessary enabling *system functions*. The model also incorporates the significance of context at the macro level for design strategic decisions and innovations and the micro level for the design and operation of the system's functions to deliver personalised and timely value. This inclusion not only enriches the model's theoretical depth and practical relevance but also enhances its applicability across various contexts, thus its dynamic nature. Reinforced by the context, the utility core guides the design to ensure the value creation is aligned with and empowers the business value proposition. It can also serve as a foundation for expanding the system's functional scope, particularly beneficial when integrated into a system-of-systems paradigm, a crucial consideration for business expansion in today's digital landscape (Porter and Heppelmann, 2014). Hence, the utility core becomes the focal point of competitive differentiation, steering design and innovation towards strategic decisions that resonate with business value propositions.

## 6. Conclusion

This paper contributes a dynamic conceptual **model** named **DHSmart** and its accompanying **canvas** for Smart PSS. This versatile tool facilitates the navigation of Smart PSS complexities in both theoretical exploration and hands-on design. It also serves as a unifying framework, facilitating meaningful interdisciplinary contributions in this rapidly evolving field. The model is developed based on a comprehensive review and structured coding scheme. At the heart of the model lie three pivotal cores: *utility*, *intelligence*, and *operational*, which collectively constitute the backbone of Smart PSS, supported by an underlying *network and infrastructure*. The 'intelligence core' is innovatively incorporated to provide a structured approach to design ***Smart*** in Smart PSS with clarity and creativity. This is to acknowledge that the Smart attribute transcends mere static characteristics and digitalisation capabilities. The Smart attribute is relative to the subtle interplay between the entire system components that can be experienced at different levels of sophistication. This inclusion aligns the digitalisation efforts with the strategic objectives and design considerations of a specific Smart PSS, including ethical imperatives. The model also advances beyond conventional Human-Centred Design (HCD) to comprehensively capture the interplay between the user and Smart PSS and integrate it into its design and development. Furthermore, the model incorporates the significance of macro and micro *context* in shaping design–informing the overall design strategy and detailed operational-level design, driving innovation, and empowering personalisation and system responsiveness. Distinguished by its comprehensiveness and dynamic–resilience to technological advancement and adaptability across varying contexts–the model stands as a robust tool for researchers and practitioners alike.

While this model is comprehensive and grounded in existing scholarly works, its empirical validation is planned. Thus, the model will be empirically refined and validated to enhance its applicability and reliability. The model's foundational nature opens diverse avenues for interdisciplinary research, including inquiries into identifying the optimal level of smartness in Smart PSS that ensures the delivery of tangible value while avoiding the digitalisation paradox. In essence, the model represents a significant step forward in a comprehensive understanding of Smart PSS and its development.

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